Cloud and aerosol lidar channel design and performance of the Geoscience Laser Altimeter System on the ICESat mission

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Abstract: The design of the 532 and 1064nm wavelength atmosphere lidar channels of the Geoscience Laser Altimeter System on the ICESat spacecraft is described. The lidar channel performance per on orbit measurements data will be presented.

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The Geoscience Laser Altimeter System (GLAS) on board the Ice, Cloud, and land Elevation Satellite (ICESat) [1] contains two atmosphere lidar channels at 532 and 1064nm wavelength for atmosphere backscattering measurements. The spacecraft was launched on January 12, 2003 and is currently orbiting the Earth performing scientific measurements. We have reported the design and performance of the GLAS surface altimeter channel [2]. This paper describes the GLAS atmosphere lidar channels design and performance.

ICESAT/GLAS has three identical lasers with one operating at a time. The laser is a diode pumped, Q-switched, Nd:YAG slab laser [3]. A doubling crystal converts about 30% total energy into 532nm wavelength. A dichroic beamsplitter separates the 532 and 1064nm signals at the receiver. The 532nm channel measures backscatterings from air molecules to cirrus clouds, while the 1064nm channel measures the backscatterings from thin cirrus clouds to dense clouds. Figure 1 shows a drawing of GLAS instrument and the receiver optics layout. The instrument parameter values are listed in Table 1.

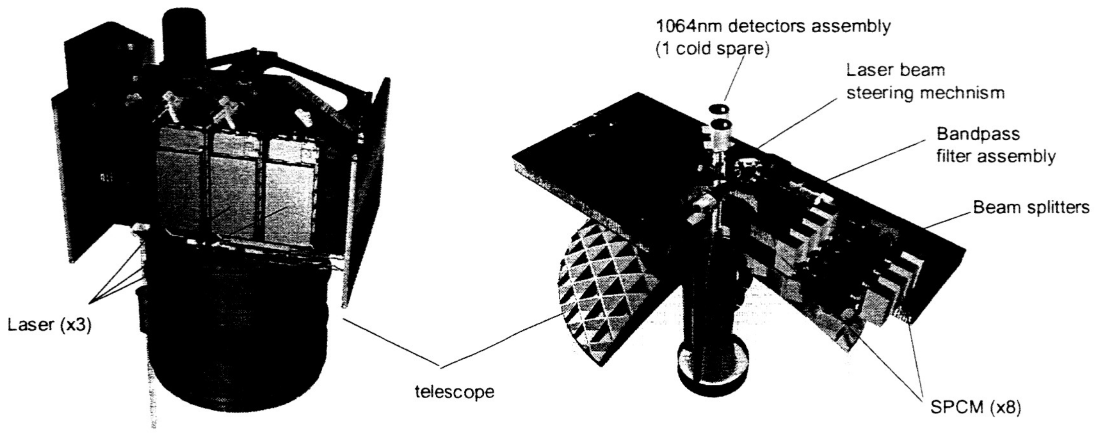

Fig 1. GLAS and GLAS receiver optics layout.

The 1064nm cloud channel shared the photodetector with the surface altimeter channel, which is a near infrared response enhanced Si avalanche photodiode (APD) with a transimpedance preamplifier all in an integrated hybrid circuit. The detected signal is filtered by a lowpass filter and then digitized at 2Ms/s.

The laser beam steering mechanism in the 532nm path consists of a voice coil dual axis turning mirror that centers the receiver field of view onto the laser spot via ground commands. The 532nm channel receiver field view is almost the size of the laser spot in order to minimize the amount of background light onto the detector.

Table 1. GLAS atmosphere lidar channel parameters

Parameters	1064nm channel	532nm channel
Laser pulse energy	70 mJ	30mJ
Pulse repetition rate	40 Hz	same
Pulse width	6ns FWHM	same
Beam divergence (full angle at $1/e^2$ points)	70 microradians	same
Receiver aperture	1 m diameter	same
Receiver field of view	0.5 mrad	0.16 mrad
Receiver bore sight alignment mechanism	n/a	0.8 microradian step size, ±8000 microradian range, <25 microradian stability
Total receiver optics transmission	75% (including the bandpass filter)	30% (including the etalon and the blocking filters)
Receiver optical bandwidth	0.7 nm FWHM	0.028 nm FWHM
Detector active area	0.7 mm diameter	0.17 mm diameter
Detector quantum efficiency	>35%	>65%
Detector photomultiplication gain	120	-
Noise equivalent power (NEP)	0.04 $pW/Hz^{1/2}$, expected to double at the end of the 5 year mission due to space radiation damages	Dark counts 200/s while new and increase at 10,000 to 50,000/s per year due to space radiation damages
Receiver integration time	500ns near Gaussian lowpass filter	500ns range bins
Receiver electronics	2 Ms/s A-to-D converter	Individual photon counting
Receiver timing accuracy (standard deviation)	8 bits	Max count rate 12 Mcts/s, each SPCM
Minimum detectable signal, 1 sec. averaging	50 pW	1 pW
Design life time	>5 years	> 5 years

The 532nm optical filter assembly, shown in Figure 2, contains a temperature tuned solid etalon and a blocking filter that matches the etalon free spectral range (FSR). The etalon material and thickness were chosen such that the etalon FSR spans 20 degree Celsius temperature range. The etalon temperature is controlled via a heater and a simple relay feedback control loop. A sample of the transmitted laser light is sent through the center portion of the etalon, one on axis and one slightly off axis, and received by a set of PIN photodiodes to give a real time measurement of the etalon transmission. A software PID (proportional-integral-differential) control loop locks the center of the etalon passband to the average laser wavelength. The overall control response time is about 15 minutes and sufficient to track on the laser wavelength change due to orbital temperature variation.

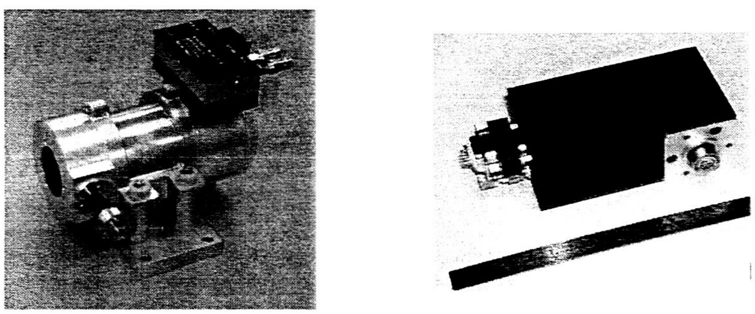

Fig. 2. GLAS filter assembly (left) and SPCM (right)

The 532nm received signal is equally divided into eight Si APD single photon counting modules (SPCM) to provide the necessary dynamic range for daytime measurement. The SPCM circuit design is similar to the commercial devices, but the part selection and manufacturing processes were modified to comply with various space qualification requirements. A patented fast response high voltage current limiting circuit is included to protect the Si APDs from catastrophic damages due to proton and other particles in space radiation environment.

Both of the 532nm and 1064nm lidar channels performed well in orbit and meet the design goals. The two channels combine can measure from molecular (Rayleigh) backscattering at upper atmosphere to high and low altitude clouds under both daytime and nighttime conditions.

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